

**THE ADULT LITERACY EVALUATOR: AN INTELLIGENT  
COMPUTER-AIDED TRAINING SYSTEM FOR  
DIAGNOSING ADULT ILLITERATES**

**Final Report**

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## ABSTRACT

An important part of NASA's mission involves the secondary application of its technologies in the public and private sectors. One current application being developed is the The Adult Literacy Evaluator, a simulation-based diagnostic tool designed to assess the operant literacy abilities of adults having difficulties in learning to read and write. Using ICAT system technology in addition to speech recognition, closed-captioned television (CCTV), live video and other state-of-the-art graphics and storage capabilities, this project attempts to overcome the negative effects of adult literacy assessment by allowing the client to interact with an intelligent computer system which simulates real-life literacy activities and materials and which measures literacy performance in the actual context of its use. The specific objectives of the project are as follows: (a) To develop a simulation-based diagnostic tool to assess adults' prior knowledge about reading and writing processes in actual contexts of application, (b) to provide a profile of readers' strengths and weaknesses, and (c) to suggest instructional strategies and materials which can be used as a beginning point for remediation. In the first and developmental phase of the project, descriptions of literacy events and environments are being written and functional literacy documents analyzed for their components. Examples of literacy events and situations being considered included interactions with environmental print (e.g., billboards, street signs, commercial marquees, storefront logos, etc.), functional literacy materials (e.g., newspapers, magazines, telephone books, bills, receipts, etc.) and employment-related communication (i.e., job descriptions, application forms, technical manuals, memorandums, newsletters, etc.). Each of these situations and materials is being analyzed for its literacy requirements in terms of written display (i.e., knowledge of printed forms and conventions), meaning demands (i.e., comprehension and word knowledge) and social situation. From these descriptions, scripts are being generated which define the interaction between the student, an on-screen guide and the simulated literacy environment. The proposed outcome of the Evaluator is a diagnostic profile which will present broad classifications of literacy behaviors across the major areas of metacognitive abilities, word recognition, vocabulary knowledge, comprehension and writing. From these classifications, suggestions for materials and strategies for instruction with which to begin corrective action will be made. The focus of the Literacy Evaluator will be essentially to provide an expert diagnosis and an interpretation of that assessment which then can be used by a human tutor to further design and individualize a remedial program as needed through the use of an authoring system.

# **Adult Literacy Evaluator: An Intelligent Computer-Aided Training System for Diagnosing Adult Illiterates**

## **I. Introduction**

This report describes the current status, milestones achieved and projected schedule of the Adult Literacy Evaluator (ALE). This spin-off project is attempting to integrate expert system, speech analysis and virtual reality technology developed at NASA into the field of adult literacy with the primary goal of creating a tool for literacy assessment with high ecological validity. The outcomes of this assessment tool will also include written diagnostic profiles and exemplar lessons in remediation strategies to be used by volunteers and staff at literacy provider organizations.

The following sections in this report include descriptions of the current project objectives, past and current developments in theory and the expert system knowledge base, the conceptual model, an updated project plan and schedule, past presentations and publications by the project team, external funding efforts and contractual research in speech analysis and recognition to be incorporated into the ALE.

Finally, the scope of this report covers the time period of March 1991 through June 1992 and describes the project's development under the current principal investigator, Dr. David Yaden. Descriptions of the work effort prior to March 1991 are not included in this document.

## **II. Current Project Objectives**

The project objectives as of 1991 have remained constant and are as follows:

- 1. To develop a simulation-based diagnostic tool to assess adults' prior knowledge about reading and writing processes in the context of their use;**
- 2. To provide interpretive, diagnostic profiles of readers' strengths and weaknesses; and**
- 3. To provide focused suggestions (i.e., exemplar lessons) for instructional strategies and materials which can be used by volunteer tutors as a beginning point for remediation with adults seeking assistance with literacy providers.**

To date, most of the work has been concentrated on objective #1 and has included interface prototyping, knowledge-base development, and the creation of literacy scenarios, i.e., real-life activities in which literacy plays a central role. Work on objectives #2 & 3 are in the initial stages.

The fact that technology for continuous speech recognition is not yet available has necessitated that the project move ahead more quickly on other fronts and develop plans for increasing the scope of the diagnostic capabilities. This increased scope and its attendant project plan is described fully in the following section. The separate development of the speech analysis component for the ALE is described in section IX.

A final caveat to the project objectives is the extent to which the technologies of virtual reality can be fully integrated into the project. Although NASA's Software Technology Branch is spearheading research in this area, the technology is still some years away from being easily incorporated into an application such as the ALE. Therefore, in order to create a virtual environment of authentic literacy materials and behavior, the project team is currently experimenting with a variety of technologies such as live and digitized video pictures with the capability of the interface to depict natural movement in each scene.

### **III. ALE: A Model for Authentic Assessment - Project Development**

Authentic, contextualized assessment is a complex issue. Yet several conceptual hurdles have been successfully maneuvered so far by the Project Team. This section will discuss critical break-throughs made in four major components of the ALE: (a) Scenario development, (b) literacy element knowledge base, (c) diagnostic continuums, and (d) comprehensive profile statements.

#### **A. Scenario Development**

1. Multi-leveled assessment. The role of the scenarios was to offer a situation in which a client could enact real literacy actions embedded in purposeful print environments. As a diagnostic tool, the ALE must be able to assess a wide variety of literacy competencies. Unlike other assessment tools which measure a very restricted range of ability, the ALE assumes that adult readers' skills and strategies vary a great deal. Thus, the ALE must be a flexible, responsive system. Also, it is important that the environmental task demands quickly adjust to the clients without their awareness due to the stigma attached to

poor literacy performance. The project team tackled this problem by creating the notion of multi-layered scenarios rather than each having a specific skill/strategy level. This means two clients working next to each other could both be in the grocery store scenario, yet one could be interacting with print at a high level of sophistication such as filling out an application for a grocery card and another could be working at a much lower level, for example, recognizing familiar logos on food items. The system will be created so that the clients' response to each action will determine the rest of the scenario. While preventing certain scenarios from being labeled as "low," this also means that frustration levels can be kept to a minimum (which is a critical issue with adults who have failed academically) and as clients gain new strategies and skills, they will encounter new print challenges within a previously experienced scenario.

2. After-scenarios. Another obstacle emerged within the scenario component. While much can be inferred from a client's interactions with print, there are large arenas of literacy knowledge, critical to traditional analysis, which could not be tapped in the scenario as originally envisioned since speech analysis is not yet available. The project team wrestled with ways to assess more realms of literacy knowledge without speech analysis and recognition. As a solution to this dilemma, the idea of *after-scenarios* was developed. Following each series of contextualized actions, such as renting a movie in a video store, In a separate simulation, the client will be asked more questions about the print experienced in that environment. In this clinical-type interview, the ALE might prompt a client to summarize the blurb on the back of a video or compare three signs in the store and determine which is the most informative. If clients want to see the document back in the original context, they just click on a certain place on the screen and the document reappears as it did in the scenario. The scenario and after-scenario partnership allows for the authenticity of real-life literacy events and the indepth probe of a clinical interview. Currently there is no other assessment tool of which the project team is aware in the education field which combines these two features.

## B. Development of the knowledge-base

1. Grounding theory through field study. The field of literacy has yet to agree upon a definition of literacy let alone upon the range of literacy elements involved in making literate decisions. So Dr. Yaden thoroughly reviewed the literature in the field extracting individual literacy elements as they were described. These were then organized logically under traditional key features such as comprehension and fluency, to offer a comprehensive pool of literacy components no where else previously compiled. The next step was to reconnect

the elements pragmatically, in other words, reorganizing the elements so as to reflect a model of literacy which not only includes the components of reading and writing but also the grounded relationships between the components. After reviewing case studies and other work in the field, Drs. Yaden and Brown determined that the information they were seeking was not in the literature and thus it is deemed necessary to undertake a study to further document adult illiteracy. The current plan is to create a grounded theory, that is, a theory of adult literacy that is actually based on observations and interactions with disabled readers in the environment. This grounding will ensure the quality and marketability of the ALE as a revolutionary diagnostic tool.

2. Client informants. The project team is also proposing an innovative design for software development by creating a team of client informants to work as fellow researchers to create the literacy model, scenarios, after-scenarios, and the interface. Rather than building a system and then testing it, the team has decided to work with the informants during the development process. This is critical with a population such as disabled readers who for various circumstances often lead very different lives than the project team members. Scenarios and after-scenarios will be created with the disabled readers' input from start to finish, thus avoiding development of inappropriate tasks. The transition to field testing will be easier due to participation and advice from disabled readers. Again, this is another consideration undertaken by the project team that will impress a business partner.

### C. Diagnostic Continuums

1. Expanded scope of literacy assessment. Traditional survey and diagnostic tests in literacy generally measure students' skills in three areas: vocabulary, comprehension, and word recognition. Other facets of reading and writing processes such as metacognition, use of strategies, and literacy concepts are rarely even acknowledged. Since adult illiterates' strengths are often in these unassessed domains, the project team faced another hurdle. The few unconventional tests that do attempt to get at these issues target very young children or are based on oral reading (as mentioned before a highly sophisticated speech analysis system would be necessary for this). The project team approached this problem by utilizing Dr. Brown's previous work which identified expanded typologies of literacy performance and continuums of behavior as opposed to discrete skill levels only. In this earlier study, she documented different dimensions of children's literacy behavior based on observational data and product analysis. Thus after considering this work, Drs. Yaden and Brown decided to create a multi-dimensional profile represented by a series of continuums that will reflect not only traditional skills such as vocabulary and

comprehension, but also reader strategies and concepts of reading and writing. The ALE will break new ground in adult literacy diagnoses with a profile that both details outcome (i.e., performance level) and actions (i.e., strategies and their accompanying knowledge base). Another unusual facet of the ALE continuums is that they will be created through field work with disabled readers. By offering a multi-dimensional profile that reflects critical facets of adult literacy, the ALE promotes a model of remediation which is based on growth and assumes the importance of the socio-psycholinguistic aspects of literacy.

#### D. Comprehensive Profile Statements

1. Summary of diagnostic interpretations and continuums. In addition to the diagnostic statements interpreting the client's behavior on each of the continuums of literacy performance, the project team has developed the notion of comprehensive profile statements or summaries which will be available to give an overview of the adult's performance across all dimensions of literate behavior. Just as the diagnostic continuums summarize across individual literacy elements, so do the comprehensive statements give a perspective within which all aspects of the adult readers' performance on the ALE can be evaluated. The comprehensive summaries will integrate the adult client's behavior across, for example, performance on textual material, strategies for approaching literate tasks, and concepts about reading and writing events. Therefore, the exemplar lessons supplied to volunteer tutors will be based upon a much broader assessment of the adult's strengths and weaknesses than any current assessment available.

#### IV. Conceptual Model of the Adult Literacy Evaluator

Figure 1 depicts the current theoretical model of the ALE. The client will go through a series of actions in various literacy scenarios. Each scenario will involve many natural literacy interactions based on authentic and common life activities, such as going shopping or renting a video. Monitoring each action of the client, the system will adjust the following literacy demands appropriately. Then an after-scenario will utilize the print materials from that environment to allow for a clinical interview. By presenting specific questions about reading and writing, this component will reveal domains of literacy that would otherwise not be assessed during authentic actions.

Each behavior will be analyzed by an inferencing algorithm, possibly fuzzy logic. Actions will be related to identified literacy elements. Another inferencing system will distribute the elements to diagnostic continuums. These continuums will be based on several broad literacy domains such as print interaction and print-coping strategies. A final inferencing algorithm will analyze each continuum and connect these to one comprehensive profile statement

which will, in turn, be tied to a set of exemplar lessons.

## V. Project Plan and ALE Roadmap

The current project plan is represented in Figure 2 and described in detail in the following narrative.

The ALE road map is split into four regions: (a) Field Research refers to work that the literacy team will do in the field to gather in-depth data about the processes and conceptions of adult illiterates; (b) Theory and Literacy Model Development describes the theoretical and conceptual milestones; (c) Software Development details the programming demands; and (d) Grants and Quest for Business Partner relays the on-going search for external funding and a business that will want to market and sell the ALE at the completion of this project. Academic seasons are marked along the road map. Each season will be described below.

### **Summer 1992**

Several fronts will move along this summer. The appropriate avenues at the university will be taken to gain consent for the field work to insure readiness for the fall. Research will continue on the diagnostic continuums and an after-scenario will be developed. The project team will work together to explore new interface possibilities and create a field prototype by summer's end. Writing a R & D grant for the National Literacy Institute will be a time-demanding task which will occupy much of July and early August. This proposal is due August 17, 1992. Efforts will continue to work with Joe Agosta, Director of Development at UH to find external funding.

### **Fall 92/ Spring 93**

During this phase of the project, Drs. Yaden and Brown will conduct a research study on adult disabled readers. During the month of September fifteen tutoring sessions will be observed and the tutor and clients in each partnership will be interviewed. From this broad group, six pairs will be chosen for intensive study over the next eight months. Through observing tutoring sessions and spending time with the disabled readers as they go about their day-to-day activities, a grounded knowledge base will develop. Drs. Yaden and Brown will also begin tutoring their own clients as to have an inside perspective on the process of remediation. During the field work, preliminary development on the scenarios, after-scenarios, exemplar lessons, and inferencing algorithm will continue.

Data analysis, occurring throughout the study, will reveal critical issues in remediation which have not been documented previously. This field work will insure the marketability of the ALE by allowing for the literacy team to create a product grounded in the needs and sensitive to the environmental constraints of adult remediation. Interface testing will enable the refinement of the prototype so that a Field Prototype 2 can be created as the field work is ensuing. It is critical to note that software development will be guided and continually refined by the data from the field. The search for external funding will continue as will the exploration of possible business partners.

### **Summer 93**

From the field research, a few disabled readers will be selected to form an informant group who will work intensely with the research team on several fronts: (a) completing the data analysis; (b) specifying interrelationships of literacy elements; (c) assessing and refining the Field Prototype 2; (d) finalizing the simulation; and (e) finalizing the continuums for the diagnostic profile. With disabled readers as essentially co-researchers immediate feedback will be available and misfires prevented. Components of the ALE will be finalized with the clients present; while being time effective, this should also be a selling point with a business partner.

### **Fall 93**

During this phase the programmers will utilize the information gathered during the previous year to implement the simulation. The literacy team will design detailed scenarios, finalize the simulation to the continuum algorithm and finalize the diagnostic profiles. Hopefully, at this point a business partner will have been secured, if not, the search will intensify.

### **Spring/ Summer 94**

While the literacy team is finalizing the inferencing algorithm from the continuums to the diagnostic profiles, writing exemplar lessons (potentially sixty), and completing each of the after-scenarios, the programmers will be implementing the rest of the ALE components.

## **Fall 94**

This final phase will involve testing in the field, further refinement, and writing of the documentation. The business partner will be integral to this phase as hopefully they would supply monies for field testing. This phase will conclude with a software program ready to be shrink-wrapped and handed off to a business to market and produce.

### **VI. Presentations**

#### **A. Justice Department, JSC.**

On March 12, 1991, a presentation of the project was given to a group of Justice Department officials by James Villarreal, Bob Way and David Yaden at the Johnson Space Center. In this presentation, the project's focus as an assessment and diagnostic tool incorporating the concepts of virtual reality was highlighted in comparison to an earlier conception of the system as being a tool for assisting the correct pronunciation of words. At that meeting, the first mock-up demonstration of the interface was presented which included live video, closed-caption TV and digitized pictures. A demonstration of the current speech recognition system being developed by Speech Systems Incorporated was given as well. The redefinition of the project as an assessment tool incorporating NASA's ICAT technology and speech recognition was well-received by those in attendance, and several justice department members volunteered federal prison sites for field-testing.

#### **B. Adult Literacy and Technology Conference, Costa Mesa, CA.**

On July 17-20, 1991, David Yaden and Bob Way made a presentation at the Adult Literacy and Technology Conference in Costa Mesa, California. This presentation included the rationale for and description of the simulation-based conception of the project as well as technical information about the research and development platform and the projected final computing requirements. From observation of other CAI programs on display at the conference, it was observed that the ALE is unique in its attempt to assess literacy in context and for the provision of intelligent feedback to both the client and literacy tutor. These features prompted several inquiries about the project both during and after the conference.

### C. Representatives from state correctional institutions, JSC.

On November, 1991 at JSC, the project was presented in detail to representatives of the National Institute of Corrections, the NASA Headquarters Technology Utilization Office, the Iowa Department of Corrections, Arizona State Department of Education and Garcz, McGing and Associates. At this meeting both Iowa and Arizona expressed a high degree of interest in the project because of its plan to incorporate real-life literacy skills as the focus of the assessment and for its provision of diagnostic interpretations and suggestions for remediation. Both states agreed to provide prison field-testing sites.

At this meeting as well, the scope of the ALE was outlined and understood to be at least three years away from completion or at a point where it could be handed off to a commercial company for marketing. Primary in this projected timeline was the fact that speech recognition technology is unable at present to analyze continuous speech, a feature necessary for the oral reading analysis component of the ALE. The meeting participants agreed to collaborate on upcoming grants from the Department of Education (DOE) depending upon the status of the ALE at the time funding was available.

### VII. Publications

Listed below in order of most recent publication date are articles disseminated by the project team describing ALE. These sources include a newspaper, conference proceedings, peer-reviewed journal and professional organization newsletter.

Yaden, D. B., Brown, L. M., Way, R., & Villarreal, J. A. (in press). *Authentic Literacy Assessment: NASA Technology Addressing Adult Illiteracy. Computers in the Schools.*

Yaden, D. B., & Brown, L. M. (1992). *The Adult Literacy Evaluator: NASA's Response to the Literacy Crisis. Mosaic: Research Notes on Literacy, 2 (2), 1,4.*

Villarreal, J. A., & Yaden, D. B. (1992). *A NASA Spin-off: The Adult Literacy Tutor. Proceedings of the Adult Literacy and Technology Conference.*

Parker, F. (1992, March). *Education Professor Using Today's Technology to Help Fight Adult Illiteracy. UHOUSTON, March 6, p. 4.*

## VIII. External Funding

To date, 30 federal and private funding agencies have been contacted by phone or letter describing the ALE and inquiring of their interest in financial support of the project. From these initial inquiries, 14 proposals have been sent to agencies interested and five (Kenan, Coca Cola, Coors, Casey & Beatrice) are still in various stages of review, according to spokespersons from those agencies. The project team is also working closely with the University of Houston Development Office and the Research Triangle Institute in following up on current proposals as well as in exploring new sources of funding not yet contacted.

Department of Education funding 92-93 for corrections, originally anticipated, has not been applied for since the ALE will not ready as a demonstration project by September 30, 1992 when the funds from these grants will be disbursed. However, federal research and development monies for adult education and technology from the National Literacy Institute are available now for competitive applications (due August 14) and a major effort will be expended by the project team in preparing a proposal.

## IX. Speech Recognition Research

In the ALE's original conception, speech analysis and recognition was to be one of the primary features of the system. To that end, two efforts have been underway to create an acceptable speech analysis component in order for the ALE to conduct an oral reading analysis, a fundamental aspect of any reading diagnosis.

### A. Speech Systems Incorporated.

In the Spring of 1991, SSI delivered to JSC a preliminary version of the demonstration software with peripheral hardware to be run on a Sun platform. This system using a combination of scoring normalization techniques such as syntactic error modeling, score normalization and phoneme error modeling, resulted in a system which had an overall 80 % accuracy rate for target words, an 80% accuracy rate for rejecting non-targets, but less than a 5% percent accuracy rate for recognizing all of the phonemes in a given word. Higher accuracy rates for this system are based on the recognition of one-syllable words, for recognizing all of the phonemes in a multi-syllable word, the system's accuracy is less than 3%.

Several aspects of the above system make it difficult to incorporate into the current project: (a) The cost of the Sun platform and necessary peripherals, (b) the fact that ALE is being designed on the Macintosh, and (c) the extremely low accuracy rates for determining all of the phonemes in both one-syllable and multi-syllable words.

**B. DKR Consulting.**

Currently, the goal of DKR is to develop a speech recognition and analysis system which will operate on a Macintosh II series computer with the first version of the system recognizing the 10 English vowel sounds in single syllable words. In this system, speech recognition is accomplished by using self-organizing feature maps (SOFM), learning vector quantization (LVQ), and hidden Markov models (HMM) operating on digitized, preprocessed speech input. The only peripheral required in this system is a MacRecorder. The first version of the system is to be delivered in October 1992.

DKR's system is best suited to the needs of ALE, partly because the developer worked on an early prototype of the system in the summer of 1991 and knows the speech analysis requirements of the system. However, the three most immediate difficulties are (a) the first version will not be delivered until October 1992, thus requiring the first prototype of ALE to be without speech recognition capabilities, (b) it will recognize vowels only and, (c) the developer cannot work full-time on the project.

# Adult Literacy Evaluator Conceptual Model





